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OCEANOGRAPHY.—*Some problems of the sea.*[1] R. L. FARIS, U. S. Coast and Geodetic Survey.

INTRODUCTION

It has been well said, I think, that "a presidential address, if there is to be any at all, should be elaborately short and elaborately simple. It should deal . . . . . with general principles, such as can be immediately grasped by every member of an audience."[2] This is good advice, and I hope you will find that I have followed it.

Noah was probably the first person of record to study the sea. He had a sea problem of navigation, of ascertaining his whereabouts and that is probably all the attention that he gave to the matter.

The first problems of the sea were probably those of navigation or perhaps such as concerned the local food supply which throughout all historic time has been drawn partly from the sea.

The seas which man found here upon his advent on earth he seems, as a matter of course, to have long considered as a part of his natural surroundings, and generally ceased to trouble himself about them—their size, their depths, their contents, or even their effect upon his life. Yet the area of the seas is much larger than that of all land areas of the earth, and their influence upon his daily life, and even upon his very nature, is profound and persistent. The very ratio of sea to land surface is essential to the existence and development of the present humankind.

It is impossible to predict or even definitely to speculate upon the effect on human life that a different distribution or a different ratio of land and water would bring about, for we have no specific knowledge of any other world arrangement with which to make comparison. I think it quite possible that not many of us have taken thought of how really our lives are dependent upon the existence and the pres-

[1] Address of retiring President of the Philosophical Society of Washington, Jan. 14, 1922. Received Jan. 19, 1922.

[2] L. FLETCHER. Brit. Assoc. Report for 1894, p. 631.

ent distribution of the waters of the oceans, and even from a practical standpoint the great majority of mankind has not bothered itself much about the matter. But when we deal thoroughly with the problems of the sea we must touch upon many fundamental branches of science.

The science of the sea concerns with like interest the biologist, the chemist, the meteorologist, the magnetician, the geologist, the physiographer, the volcanologist, and others, with special subdivisions of their lines of investigations. Also the navigator and the civil engineer have their important practical problems dealing with the sea. Many branches of science meet in and upon the sea, and their boundaries merge into each other.

The sea has made for us a clue to much of the past surface history of the world, for in its depths the remains of the past life of the sea have been filed away as in the archives of nature, and the sedimentary rocks which have been formed tell us something of the physical history of the earth.

A study of the life in the sea is no longer one of scientific interest only, but one of pressing economic importance, as an added source of supply of human food for the ever-growing populations of the earth.

From a biological standpoint, are there any deserts in the sea? Is it possible to cultivate the sea as we do the land, or as we do our oyster resources, or our streams and lakes by stocking with fish?

To utilize our land areas economically, topographic, mineral, forest and other special surveys are essential. Just so, it is important to have a scientific survey of our ocean areas to enable us to take stock of its natural resources, and, having this, thereby to be in a position intelligently to develop and to utilize its resources in an economical and efficient manner.

Aside from being the highway of the commerce of the world, do we also need to use the food resources of the sea for the maintenance of the human race? Or, in other words, must we depend upon the sea to provide a portion of the food necessary for the existence of the coming populations? Does the human body now require for its best development any essential elements of food that can be supplied by the sea only?

If these questions are answered in the affirmative, then, among others, the sea food problem requires our most intelligent attention, especially as the people are even now taking thought of their food

supply, which the tillable land areas of the earth are daily growing less and less able to meet, as evidenced by the rising basic costs of food. Sea foods have been looked upon as desirable, but not absolutely essential, parts of human diet. They may soon become necessary to supplement an inadequate food supply from the lands.

It was the belief of Sir John Murray that the sea is capable of a productivity equal to that of the land. It is generally estimated that less than five per cent of man's food now comes from the sea. If so, then the sea has unrealized possibilities of utilization that are vast from the economic standpoint, and a comprehensive study of these possibilities should not be overlooked or neglected, especially by maritime nations.

As the land areas are made subservient to the practical needs of man just so must the sea be made more useful in supplying the needs of the human race, both physical and cultural. But the utilization of the resources of the ocean must and will follow its scientific investigation and study. Let us find out what is in the sea, and then learn how to apply it to our needs.

As our frontiers are pushed farther and farther toward the limits of our country we hear more and more about the conservation of our natural resources, while here on the borders of the continent lie untold resources awaiting our investigation and industrial development. So whatever science can do in its investigation of the sea and all that therein is, cannot fail to have its important interest for us in the practical bearings it must eventually have upon our daily lives.

In the sea, as in no other place, do we observe the tireless energy of the universe depicted at all times. The hydrosphere, like the atmosphere, is never still in all its parts. It epitomizes and visualizes the energies of creation. And the inhabitants of the sea, by long processes of adaptation, are no doubt dependent upon, and aided by, these ceaseless motions which assist their distribution and prevent overcrowding, and aid in the provision of food which is a necessary condition of their life. The circulation of the waters of the sea is a vital benefit to the life of the ocean creatures, just as air circulation is vital to the living organisms of the land. The circulation of the waters in the great ocean streams has also a climatic influence upon the life on the land areas of the world as well as upon the life in the sea. It is the climatic balance wheel for many regions, ever striving toward an equilibrium which fortunately is never quite attained. The sea has its seasons no less than the land.

In fact, as we learn more and more of the physical facts of the sea, we also learn of their important influence upon our lives.

I suppose that nearly all the problems of the sea that are really worth while have already been suggested and more or less studied by some one, and many of them are at least partly solved, but my wish is to emphasize strongly the necessity for an intensive pursuit of those that have scientific or economic value, and for concerted effort and standardized action, that an awakened and sustained interest may be had in those problems, especially by all those nations whose borders touch the oceans and who thereby must the more readily realize the importance of, and be much interested in, such matters.

Much more of actual observations at sea and in the sea is needed to verify existing theories or to modify them to conform to the further facts of observation.

The mechanical problems of the sea are more nearly solved than its physical ones. The helps to the navigator are far advanced, and the life-saving and property-saving appliances are well up to date, so that the mariner sails on a more familiar sea than the oceanographer or the geophysicist. But this is only because his problems were the more immediate, and the aid of the scientific method and of science was first applied in his direction for very obvious reasons; he has been here with his practical problems since the birth of modern science and has stood ready to apply its findings to the betterment of his art. The applications of radio communication have become the genius of ocean navigation, and of longer distance weather predictions.

Yet it is not possible clearly to separate the pure science from applied science in oceanography, as the needs of the one stimulate the other, and the discoveries of science soon become the necessities of the practical navigation and other economic uses of the sea.

OCEANOGRAPHY

Oceanography, the general term by which the science of the sea is now come to be designated, is a comprehensive term which embraces a number of rather distinct branches of investigation and study, but many of which, owing to the nature of the problems, are generally carried on simultaneously. It certainly would be most economical and efficient that as many as possible of the physical investigations of the sea be carried on simultaneously by the same exploring expedition. The equipment for sea exploration is expensive at best, so that the

more comprehensive the investigations can be made, the more economically will the results be obtained.

Oceanography as this term is now applied is not an old science. Some twenty years ago Sir John Murray[3] said of it:

> The recognition of oceanography as a distinct branch of science may be said to date from the commencement of the Challenger investigations. The fuller knowledge we now possess about all oceanic phenomena has had a great modifying influence on many general conceptions as to the nature and extent of those changes which the crust of the earth is now undergoing and has undergone in past geologic times. Our knowledge of the ocean is still very incomplete. So much has, however, been acquired already, that the historian will, in all probability, point to the oceanographical discoveries during the past forty years as the most important addition to the knowledge of our planet since the great geographical voyages associated with the names of Columbus, DaGama, and Magellan at the end of the fifteenth and the beginning of the sixteenth centuries.

There are probably no longer any frontiers on land or sea to explore, except perhaps some parts of the polar areas, yet upon the sea there is one region of two million square miles that has never felt a cast of the sounding line, nor much of other investigation.

The extreme depth of the ocean has probably been approximately approached, and now turns out to be somewhat in excess of 5300 fathoms (31,800 feet), somewhat more below sea level than the highest elevation of the land above the sea; thus making the summit of the highest mountain about ten geographic miles above the deepest known "deep" of the ocean.

While we now have much information about the physical geography of the oceans and detailed surveys have been made of their borders in the more advanced countries of the world, there yet remains the larger part of the sea coasts to be surveyed and mapped by such modern methods and equipment as will meet present and future requirements of science, engineering, and commerce; especially is this true of the coasts of the Pacific Ocean, and of the polar regions.

A knowledge of the physical form of the ocean basins is fundamental to almost all of the branches that go to make up the whole science of the sea, and, together with other physical facts, is a guide to many industrial possibilities existing therein.

I think that there can be no doubt that the lack of accurate knowledge of the form of the ocean basins has already retarded industrial progress, commercial development, and scientific and cultural advancement of the world.

[3] President's address, Section E (Geography), Brit. Assoc. Report for 1899.

In the Atlantic Ocean, beyond the 1000-fathom depth, there is now one sounding for about each 12,000 square miles; in the Pacific, one sounding for each 25,000 square miles; and in the Indian Ocean one sounding for each 26,000 square miles. The depths of the polar seas have been explored only to a most limited extent or virtually not at all. Owing to the methods of navigation and of deep sea sounding, when the earlier of these soundings were recorded, it is quite possible that their positions and depths now ought to be verified by modern methods.

The major part of the sea coasts of the world is not yet surveyed and charted with the accuracy now needed, and many thousands of miles of the coast lines are not surveyed at all, and still other parts not even approximately sketched.

In our own country nine-tenths of the coast of Alaska is not yet surveyed, and the Pacific Coast of Continental United States is for the large part yet undone, while the need for surveys is urgent and commercial development is retarded and delayed.

Only about one-seventh of the land area of the world is in any wise adequately mapped, and the form of the sea bottom is proportionately not so well known as the topography of the land. The surface of the sea holds less of interest to mankind than the surface of the land; however, to the man of science, the bottom of the oceans, if it could be exposed to view, would no doubt reveal equally as much of scientific and popular interest as the land surfaces.

We have been mapping the land by various means and methods for many centuries, while the mapping of the coasts and ocean basins has been undertaken seriously for a bare century and a third, and with only a comparatively small number of vessels and by only a few nations. So it is readily understood why the undersea form of the earth is not yet known to any very conclusive extent. In the matter of charting the sea coasts and depths of the oceans, it is well known that all nations are lagging far behind the practical needs of ocean commerce.

At the time of Columbus' voyage of discovery to the new world there were no charts showing the depths of the sea, nor the exact boundaries of any ocean. In the year 1504 Juan de la Cosa made a map showing soundings in shallow waters. Magellan, in the year 1521, was probably the first to attempt to sound the ocean depths.

Up to the present time the total number of soundings that have been charted in the three larger oceans beyond the 1000-fathom

depth probably does not much exceed seven thousand,[4] including many of the earlier ones that ought now to be verified, both as to position and depth of water; or an average of one sounding for each 17,000 square miles. To compare this with what ought to be done in order to have a complete general deep sea survey it should be stated that at least one hundred and fifty thousand soundings are needed, spaced at intervals of about thirty miles, with necessary local development. This would require ten ocean-going ships in continuous service for ten years. And this means that each vessel must take four or five deep sea soundings every day of the year throughout these ten years. If, however, these vessels should carry on other oceanographical investigations, as they most certainly should not fail to do, the time would be much longer.

From physiographic and biologic standpoints the borderland of sea and shore, the so-called continental shelf, holds a closer claim upon our attention than any other part of the sea. This is the most populous part of the ocean as regards the different forms of sea life; and here also the physical forces of the sea are most manifest and effective in producing the physiographic transformation that the face of the earth is experiencing without cessation.

The force of the ocean waves is spent upon the sea shores in an endless and tireless evolution. The study of the processes of erosion and accretion of sea shores is one of importance to the scientist and the engineer alike. A study of these involves a knowledge of tides, currents, and wind-produced ocean waves. The causes must be studied and the effects observed from time to time.

The larger part of the coast lines of the oceans, like the interior of the continents, yet remains to be charted in accordance with the present-day requirements. The sea bottom from the shores to the edge of the continental shelf should be surveyed and mapped to meet the needs of commerce, industry and science, all of these being vitally concerned in the undersea physiography of this transition belt between the land areas and the deep sea.

A survey and study of the ocean depths surrounding the islands of the seas will doubtless do much towards giving us a clearer conception of coral formation and growth, and add to our knowledge of subsidence or emergence of land areas.

The charting of the ocean basins from their shores to their profoundest depths is one of the outstanding problems of the sea. The

[4] MURRAY and HJORT. *Depths of the Ocean*, p. 131.

importance of it is especially known to all who have anything to do with oceanography. The problem is also so large that nations are thinking more seriously than ever before of how its solution can be expedited by cooperative means. It is now fully realized that it is a problem for all nations; it is no longer considered national but is admittedly international.

The most recent evidence of the crystallization of authoritative opinion concerning the international character of the hydrographic survey of the oceans, is the formation during the past year of the International Hydrographic Bureau, which has in its membership representatives of most of the maritime countries of the world. The object and powers of this Bureau are stated essentially to be:

> The establishment of a close and permanent association between the Hydrographic Services of the Associated States, to coordinate their efforts with a view to rendering navigation easier and safer in all of the seas of the world, to cause the national officers to adopt the Resolutions taken by the various International Hydrographic Conferences, to try to obtain uniformity as far as is possible in hydrographic documents, and finally, to advance the theory and practice of the science of hydrography.

Among the subjects which the Bureau suggests for study is "Researches on the subject of the constitution of the earth, in so far as it affects hydrography."

In reference to many other subjects that make up the science of the sea, the present-day attitude of men of science in regard both to the magnitude of the problems confronting them and to the essential need for unified action of all nations in attacking the problems now pressing for solution, is well reflected in the meeting of the First Pan-Pacific Scientific Conference fittingly held in Honolulu in August, 1920.

The papers presented and the subjects discussed at those meetings are quite sufficient to convince us that much the greater part of oceanographic work lies ahead of us, and that adequate progress requires the efforts of all nations, and also that the work of the surveys and investigations should be henceforth speeded up materially.

Oceanic circulation.—Now briefly to touch upon some other of the larger problems of the sea; the courses of the currents that make up the system of oceanic circulation have been mapped in a general way but our knowledge of these streams is far from satisfactory. Our information concerning the strength and direction of ocean currents is largely dependent upon the set experienced by vessels traversing the oceans. And this is based on the difference between the true and the dead-reckoning positions, which does not permit of great accuracy

in determination. Supplementing the information from this source there are a large number of records of drift bottles, wrecks and other floating objects. But at best these permit conclusions of a qualitative nature, *only*. We still lack observations that will permit of quantitative conclusions, and these can come only as the result of systematic observations.

Results of a divergent character are found in the records of drifting objects. It is only by the use of great numbers of records of this character, that conclusions, even approximately correct, may be reached. Thus the whole subject of oceanic circulation is still relatively a virgin field. For each of the currents investigations are needed to determine its extent, its width, vertical and horizontal velocity distribution, and its wind and seasonal variations.

Even in the case of the Gulf Stream, upon which considerable good work has been done, there is still needed much work of a quantitative kind. For instance, it is known that the position of the velocity and temperature axes of the stream are not necessarily coincident. But the exact relation between the two yet remains to be discovered. Likewise the seasonal changes in the positions of these two axes, and the variations in velocity and temperature due to changes in the velocity and direction of the winds, yet remain to be investigated. Considerable additions to our knowledge of the Gulf Stream can yet be made regarding the horizontal and vertical distributions of velocity of currents, temperature, density, salinity, and their variations with the winds and seasons. This involves, also, elaborate tidal and current observations in the Caribbean Sea, the Gulf of Mexico and the adjacent waters of the Atlantic Coast, and possibly across to the European Coast.

Tidal currents.—Intimately connected with the tides and forming a part of the same phenomenon are the tidal currents. Out of sight of land, tidal currents are generally very weak. But there they offer an interesting field for study, since off-shore they are most frequently of the rotary type. Close inshore considerable work remains yet to be done to bring out the characteristics of local currents, especially in the less frequented places of the world. There is also need for investigations of a local character to determine the changes in the current velocities due to winds and changes in atmospheric pressure.

Such investigations are of the greatest importance, aside from their scientific value, in safeguarding navigation, in harbor works, and in coast protection.

Tides.—Of all the phenomena of the sea, the tides seem to have been among the first to attract man's attention, although there is an interval of at least two thousand years between the earliest mention of the tides that has come down to us, and the time when Jeremiah Harrox first undertook a series of three months' continuous tidal observations in the year 1640.

Our knowledge of the tides is based almost entirely on observations confined to the immediate vicinity of the coast. Observations have not yet been made in the wide stretches of the open ocean; and even close inshore where the difficulties of measuring the rise and fall of the tide are much less, little has been done, and there are numerous localities along the coasts where accurate information is still wanting. There is need of investigations to determine for each locality the changes from the normal heights of the tide, due to wind and changes in atmospheric pressure.

The tide-producing forces are definitely known, but the problem of correlating these forces with the time and height of the tide at all places on the earth by means of a general formula is yet to be solved and much more of observation is needed where none as yet exists, especially in the open sea, for the settlement of the question of the general tidal theory.

Mean sea level.—Closely related to the subject of tides is the question of mean sea level and its relation to elevation of the land of the sea coasts. By mean sea level, I mean that resulting from continuous tidal observations over a period of at least one complete lunar cycle of approximately nineteen years' duration.

I do not see just how we can know anything definite about the variations of mean sea level. The sea areas are so much greater than the land areas of the globe that I think we must assume for all practical purposes that mean sea level remains practically constant and that any changes in vertical distance between reference points on the sea coast and the mean ocean surface are due to the movements of the land, and not to variations of mean sea level. The problem therefore becomes one of determining the elevations of the coasts with reference to the mean level of the sea. This problem is of much importance to the engineer and the scientist, especially the geologist and geophysicist. Measurements on land and sea are all referred to sea level wherever a vertical reference point is required. Many of our industrial works are based on this reference plane, and on account of its invariability and readiness of reproduction, it is a natural standard.

It is therefore important that the relation of the land elevations to sea level be studied and accurately known. A knowledge of this relation is vital to the study of the subsidence or emergence of land areas.

That there have been great uplifts and subsidences in the surface materials of the earth in past ages is well known. How long these were in being accomplished, especially the uplifts, is not so well known. Adjustments of the material of the lithosphere have not ceased, and these adjustments generally result in some changes in reference to sea level.

Of course the duration of one generation is a short time in which to study by physical observations any facts of subsidence now in operation, but the observations should be arranged by this generation and carried out systematically and handed on to the next, so that cumulative evidence may later establish what the facts are relative to changes in land elevations.

These observed facts must be closely related to tidal observations of one or two years' duration all along the coasts, connected by lines of precise levels. These tidal observations must be simultaneous with tidal observations at standard base tidal stations where a long series of observations have already been or are being secured.

No systematic work for accurate subsidence determinations has been carried out anywhere, as far as I know, though there are a few cases where precise levels were run between bench marks after intervals of from 25 to 78 years.[5] Our present knowledge of the changes in the relation of sea and land elevations (except those due to sudden changes) depends almost entirely upon deductions from geologic evidence found in the fossil remains of sedimentary rocks, studies of coastal erosion, and perhaps in the study of coral reef formation about the coasts and around the islands of tropical seas.

In this connection it seems proper to emphasize the importance of having hydrographic surveys about the islands of the tropical seas especially, not only for geographical reasons and for purposes of safer navigation but also for the use in the study of coral formation and also to afford us information of shore line changes effected through subsidence, uplift, and erosion.

Terrestrial magnetism.—The problem of the earth's magnetism is about the most difficult of all the unsolved problems of geophysics. The data requisite for the study of this problem include magnetic observations over the ocean areas, not only to measure the magnetic

[5] Geograph. Rev. 3: 136–137. 1917.

elements but to ascertain the secular change of these elements, to outline the disturbed areas, and to discover the effect of ocean depths.

As far as I am aware only two specifically organized magnetic surveys of the oceans have ever been established, that of Edmund Halley in 1698, and that at the present time of the Department of Terrestrial Magnetism of the Carnegie Institution of Washington; the latter being by far the most comprehensive and extensive, covering the seas from latitude 60° south to 60° north, this sea work being supplemented by many hundreds of stations on land in countries where such work is not being actively carried out by the nations themselves.

Most excellent work is being done, and the first magnetic survey of the oceans may be said now to be nearing completion, but observations for the secular change data must be kept up. To keep the secular change data up to date, and to fill in as yet unsurveyed areas, will probably require the time of one expedition continuously.

Additional magnetic stations are especially needed in the polar regions, especially in the north polar area. No opportunity should be neglected by any surveying or exploring expedition to obtain magnetic and allied observations wherever needed. Such electrical observations as may be found necessary and practicable should also be carried out in connection with the magnetic observations at sea.

Gravity observations.—A problem of much importance in the study of the physics of the earth is the determination of the intensity of gravity at sea first, to furnish further information that will enable us to ascertain more accurately the shape of the earth, and second, to determine the distribution of the densities in the so-called "isostatic shell" of the lithosphere.

Researches in this and other countries have made it certain that the outer seventy miles of the earth's material is in a state of approximate isostatic equilibrium. If we assume a surface seventy miles below sea level under the continent and on this surface lay out squares approximately one hundred miles on a side and extend vertical planes from these sides to the surface of the earth, we should have the same mass in each of the columns, though some of the columns would be a mile or more longer than others. In other words, each column of equal cross section is found to have about the same pressure on the nucleus at a depth of seventy miles below sea level as any other column.

Do these conditions exist under the ocean? The answer to this question requires the obtaining of observations for the intensity of gravity over ocean areas.

Observations for the determination of intensity of gravity have been made at sea by several types of apparatus, but the accuracy of these observations has only been sufficient to show that the intensity of gravity under ocean areas followed closely the laws of change of gravity with latitudes that are found to obtain over land areas, but the observations are not accurate enough to test the isostatic condition of the ocean basins.

Some modification of the present instruments and corresponding change of method of observation are needed, or possibly some instrument devised along entirely new lines from those heretofore employed finally may be found necessary to get the accuracy required.

The solution of this problem is a matter of prime importance to geologists and geophysicists in many of their studies.

Meteorological observations.—To know the state of the weather in advance of its occurrence is an important matter to us whether we be on land or sea, and the economic value of such information is well known. In fact a foreknowledge of the weather has had such an immediate economic value that the practical side of meteorology has developed to a greater degree than the theoretical side of the problem.[6]

We have much less meteorological observational data over ocean areas than for the land areas, though the ocean areas are of much greater extent. The gathering of meteorological data more completely over the regions of the oceans is an important problem of the sea, and for us especially in the Pacific Ocean and Bering Sea. In this all ships that traverse the oceans can also continue to render valuable service, by making meteorological observations, reporting them by radio, and following with full reports by mail.

The need for much more ocean meteorological data is plain, and their scientific and practical value so evident that no opportunity for obtaining them should be disregarded.

Another problem said to be of promising importance is the observation of the tides and their correlation with the paths of approaching hurricanes.[7]

Ocean temperatures.—One of the most striking deficiencies in our knowledge of the physical facts of the sea is that of ocean temperatures. In the whole of the vast Pacific Ocean, for example, there are only something like seven hundred lines of temperature observations,[8] by

[6] Proc. Nat. Acad. Sci. **6:** 561.

[7] Science **52:** 638–639. Dec. 31, 1920.

[8] Annalen der Hydrographie, **38:** 5. 1910.

far too meager a number with which to delineate an isothermal chart of such an ocean. Lines of temperature observations are much too few in all of the oceans, to say nothing of temperature data sufficient for ascertaining the facts of variations of temperature, seasonal or other at any place, except in the regions about the North Sea, the Baltic and in the Mediterranean.

A knowledge of ocean temperatures at all depths, and for different seasons of the year, is one of great significance to the science of physical oceanography, and is one of its outstanding needs at this time. It is fundamental to the study of ocean circulation and to the problems of the marine biologist, and is believed to be a fair index, as well, to certain configurations of the sea bottom.

Closely related to the problem of ocean circulation and to some of the problems of marine biology is the salinity of the ocean waters. The salinity varies throughout all of the waters of the sea, and a better knowledge of its variations, especially the vertical distribution, is most important, and is as yet not even so well known as the vertical distribution of temperature.[9]

Sedimentation.—In oceanographic surveys bottom specimens should be secured when sounding the depths of the sea, in order to secure samples of the materials of the ocean floor for the study, among other purposes, of sedimentation, which is fundamental to the geologist in considering sedimentary rocks. The character and chemical constitution of the deposits on the ocean floor is of prime importance to the marine biologist and the volcanologist. The bottom specimens should be secured in such a way that it can be ascertained how the deposits are serially laid down, and this requires as deep a penetration as possible for the specimen-gathering device.

In contemplating the many problems connected with a study of the sea it is at once realized that it is not possible even to mention many of them within the time at my disposal and one at once comes to the thought how great is the task of finding out what is in the sea, and it is the magnitude of this task that should urge the maritime nations of the world to a more serious and active consideration of those problems as to how they may be more expeditiously carried out. To this end international cooperation is essential, for it is a world problem, and of equal importance to all.

The units for the oceanographical investigations should be as comprehensive as can efficiently work together. For the most effi-

[9] Ency. Brit. ed. 11. p. 983.

cient service the vessels employed on oceanographic work should be designed and constructed for that specific purpose; the design to be based on a careful consideration and study of the purpose and requirements involved in the investigations that are to be carried out. A laboratory should be provided on board the vessel so that chemical, physical and biological investigations can to some extent be carried on while the vessel is on the working grounds. The instruments and equipment, and the methods of their use, should be standardized and up-to-date. And in order to secure standard instruments and methods these matters should be considered and passed upon by a body composed of competent representatives of all cooperating nations. This body should also draw up a manual of instructions for the oceanographic work. Then all investigations carried out at sea by the different expeditions would be of a readily comparable character.

After the sea investigations have been made the most important thing is the earliest possible publication of the results in such form, at least, as will make them accessible to all students of the subjects concerned. There are a number of institutions already in existence, and others could be established if necessary, where this could be done. In other words, these institutions would be the clearing houses where the results of the oceanographic investigations would be studied, correlated, and published.

CONCLUSION

My thought and purpose throughout this paper has been to put before you in a most general way, the fact that although much has been done in the investigation and study of the sea, and that also there may be but few, if any, new regions to explore or new problems arising, yet as regards the details of existing problems yet to be searched out and correlated, a good beginning only has been made, and that the work yet needed to be done is so large as to require the combined effort of all maritime nations, also that the need for the work is really more pressing than its present rate of accomplishment indicates.

Let us do what we can to popularize this subject; to show its scientific and cultural as well as its economic aspects. Let us interest the public in the value of knowing and cultivating these great ocean fields, to learn more of Nature, as well as to make the lives of coming generations more certain and secure.

Science applied to our national resources, has made the great industrial development of America, but with this development the needs of the rapidly growing nation have correspondingly increased, so that today we are forced to take thought of the remaining natural resources of the land. A study of the sea will widen the field of our natural resources as well as extend the limits of human knowledge and culture.

ENTOMOLOGY.—*New species of the coleopterous genus* Trox. H. F. LOOMIS, Bureau of Plant Industry. (Communicated by O. F. Cook.)

Preparatory to describing a very extraordinary species of *Trox* recently collected in Arizona, an examination of the closely related forms was made which led to interesting findings regarding the classification of these species. The identification, on external characters, of the species of this genus has been considered an easy matter and the genus has received little attention from systematists for many years. As in many other insects, very reliable specific differences are exhibited by the male genitalia in this genus. This structure shows that in the material hitherto identified as *scutellaris* Say, in the National Museum, three very distinct species of great superficial resemblance are included. That this resemblance has caused these species to be confused in most collections is probable and other cases of a like nature may occur, an examination of the male copulatory organs being necessary to separate the species

In the specimens of *platycyphus* and *scutellaris* the wings were found to be greatly atrophied and represented by only a short and very narrow vestige while in *oligonus* they show much better development and bear far more resemblance to normal wings.

Only the larger species, those having the thorax strongly constricted behind, are dealt with in this paper. The male genital organs of all the species belonging to this group in the United States have been figured to facilitate recognition of the species. The figures were made with the aid of a camera lucida and all are drawn to the same scale. The copulatory organs of the female probably will also exhibit good specific characters but they are not considered here.

Six species described by LeConte in 1854 have been reduced to varietal rank under *scutellaris* and *punctatus* but the writer has been unable to identify any of these from the external characters mentioned in the original descriptions. Their validity can be decided only after study of the genitalia of the LeConte types. In this paper specimens collected at Pueblo, Colorado are assumed to be *scu-*

tellaris Say (type locality, "Upper Platte"), and a specimen of this typical form is before the writer from southwestern Texas (between Pecos River and the Guadeloupe Mountains).

Trox platycyphus Loomis, sp. nov. Shape oblong-oval, the color black and shining when clean. Length 14 to 19 mm. Habitat, southern Texas.

Thorax strongly constricted at basal third; posterior angles obtusely rounded, a slight emargination immediately in front of them; tubercles strongly shining, much more sparsely and coarsely punctured than the rest of the surface; tubercles of the posterior series oval, the median pair larger; in front of each outer one and belonging to the anterior series is a smaller tubercle; the usual ridges of the median pair of tubercles of the anterior series coalesce causing the tubercles to appear broad and flat; from each of these, on the inner side, a narrow, usually unpolished ridge extends backward between and nearly opposite the middle of the inner pair of tubercles of the posterior series. Elytra with the tubercles transversely confluent, much flattened, smooth and shining; rows of large and small tubercles alternating, four rows of the large, six of the smaller, two of these smaller rows between the suture and the first large row; series of punctures much confused by transverse coalescence of tubercles; entire surface of the elytra glabrous.

The male genitalia large and with very pronounced constriction near the apical third; median lobe not attaining apex of the lateral lobes; outer sides of lateral lobes almost parallel with a very abrupt constriction on the apical third which reduces the width of the lobe nearly one half, the lobe then continuing to a rather broadly rounded extremity; dorsal surface of lateral lobes at the constriction abruptly declining giving the narrowed apex a lower level; basal pieces long and rather broad. FIG. 1, A.

Type and paratypes No. 25198, U. S. National Museum.

Described from nineteen specimens from Cotulla, Texas, collected April 17, 1906, by F. C. Pratt. Other paratype localities in Texas are Knippa and Sabinal, one specimen from each (*F. C. Pratt*), and San Diego, two specimens (*E. A. Schwarz*).

The pair of complanate median tubercles of the thorax, the confluent elytral elevations and the form of the genitalia are the salient features of this species and separate it from *scutellaris* and the species which follow it.

Trox oligonus Loomis, sp. nov. Large and broadly oval, robust species; shining black when clean. Length 16 to 18 mm. Habitat, Texas.

Constriction of thorax moderate and resembling *scutellaris* although not as long; margin in front of hind angles faintly emarginate; tuberculation as in *scutellaris*. Elytra with rounded and moderately distinct tubercles in ten rows, none of which predominates; usually a few spicules in a small patch behind each tubercle; intervals between the rows of tubercles with a series of punctures which are finer than in *scutellaris*. Vestigial wings short, rather broad.

Male genitalia comparatively small; sides of lateral lobes not constricted at apical third as in *scutellaris* and the preceding species; tip of median lobe more acute, reaching nearly to tips of the lateral lobes; basal pieces broad and long. FIG. 1, C.

Type and paratypes No. 25199, U. S. National Museum.

Described from a series of nine specimens from Texas; five from the type locality, San Diego, collected by E. A. Schwarz, April 30 to June 12, 1895, and

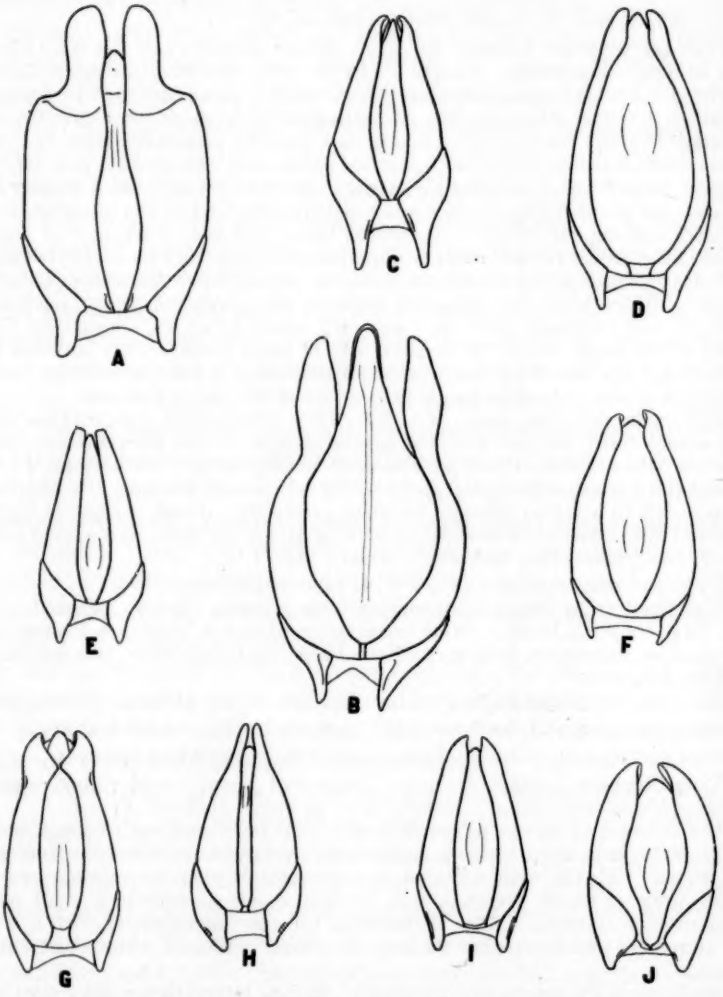

Fig. 1. Male genitalia of *TROX*.—A, *T. platycyphus*, n. sp; B, *T. scutellaris* Say; C, *T. oligonus*, n. sp.; D, *T. inflatus*, n. sp.; E, *T. scabrosus* Beauv.; F, *T. monachus* Hbst.; G. *T. asper* Lec.; H, *T. suberosus* Fab.; I, *T. punctatus* Germ.; J, *T. carinatus*, n. sp.

one specimen from each of the following localities,—Encinal (*J. D. Mitchell*), Santa Rosa (*H. S. Barber*), El Paso (*F. C. Pratt*), and Lamesa (*E. G. Holt*).

Distinguished by the rounded tubercles of the elytra which are seldom confluent and in rows of equal size, and also by the size and shape of the male genitalia.

Trox inflatus Loomis, sp. nov. Body smaller and more slender than *scutellaris*, elongate-oval; color black and shining when clean. Length 14 to 15 mm. Habitat, Arizona.

Thorax strongly constricted, in this respect resembling *suberosus;* hind angles broadly rounded and with only a slight emargination of the margin in front of them; disc moderately elevated, tubercles distinct, the outer ones of the basal series the larger; in front of each are two smaller ones belonging to the anterior series which, with the large median pair, is composed of six tubercles. The four rows of elongate and flattened tubercles of the elytra hardly to be distinguished from the intervals between them; these intervals are raised at short distances into slightly less distinct elevations which lack the small tomentose areas following the tubercles of the major series; usually a few small spicules in the depressions of the intervals, a single spicule located above each of the deep punctures on either side of the intervals; elevations of the intervals often confluent with the tubercles of the adjacent rows; second series of tubercles ending on apical fourth in a faint umbone. FIG. 1, D.

Type and allotype No. 25200, U. S. National Museum.

Described from two specimens; a male collected in a moist recess among rocks on the top of a desert peak near Sacaton, Arizona, November 23, 1921, by H. F. Loomis, and a female collected on Ash Creek in the Graham Mountains of Arizona, July 2, 1914, by E. G. Holt.

From the size and general shape of the copulatory organs of the male this species is related to *scutellaris*, but it differs in having the median lobe greatly inflated and visible above the lateral lobes when viewed from the side; the tip of the median lobe is less slender and the lateral lobes are not abruptly constricted on the outer side near the apical third above which the lobes are not as greatly expanded.

Trox carinatus Loomis, sp. nov. Form oboval, less compact; color black, surface feebly shining when clean. Length 12 to 13 mm. Habitat, south central Arizona.

Constriction of thorax longer than in any other species dealt with, emarginate throughout its length; margin sharply incised in front of hind angles which are acute and remote from the humeri; disc strongly elevated; tuberculation resembling that of *asper* though hardly as coarse. Elytra each with four prominent carinae replacing the rows of large tubercles, the two inner carinae more pronounced; second carina ending on the apical fourth in a tomentose and dentiform umbone; all carinae with small tomentose patches on the outer side; intervals between the suture and the first carina, between the carinae themselves and between the last carina and the elytral margin each with two rather widely separated rows of large and deep punctures; surface between the rows and between the punctures in the rows smooth and evenly rounded. Front tibia with a well developed tooth at apical third; upper face with two rows of rather large punctures.

Copulatory organs of the male relatively short and broad; median lobe

stout, not attaining tips of the lateral lobes; inner margin of lateral lobes strongly arcuate; basal pieces broad and enfolding much of the lateral lobes. FIG. 1, J.

Type and allotype No. 25201, U. S. National Museum.

Described from two specimens; a male collected with the male specimen of *inflatus* near Sacaton, Arizona, November 23, 1921, by H. F. Loomis, and a female collected in the "nest of a rat among rocks" (probably *Neotoma*) near Tucson, Arizona, January 2, 1897, by H. G. Hubbard.

This species should probably be placed after *punctatus;* the carinate elytra, the form of the thorax and the genitalia distinguishing it from that species and all others. Tibial punctures are found in most of the species of *Trox*, but their size and disposition have some specific importance. In *scabrosus*, *monachus* and *asper* these punctures are small or entirely lacking, in the other species here treated the rows are much more irregular than in *carinatus*.

ABSTRACTS

At a meeting of the Council of the Washington Academy of Sciences on January 16, 1922, it was decided to discontinue the section of formal abstracts in the JOURNAL. It will be replaced by a section devoted to brief notes of recent publications.

PROCEEDINGS OF THE ACADEMY AND AFFILIATED SOCIETIES

BOTANICAL SOCIETY

A special meeting of the Botanical Society of Washington was held at the Cosmos Club on Monday, June 26, 1921, to hear Prof. J. F. ROCK of the Office of Foreign Seed and Plant Introduction, who had just returned from an extended trip in the Orient, where he traveled up the rivers of Siam and Burma and through the forests to find the chaulmoogra oil trees. This oil has lately been used in Hawaii for the treatment of leprosy with such success that already two hundred patients have been declared free from all sumptoms of the disease. According to Hindoo legend and literature, moreover, this oil has been used for a thousand years by the natives of the Far East.

The trip was made by Prof. ROCK for the purpose of investigating the various species of *Taraktogenos* and *Hydnocarpus* and to collect viable seeds for germination purposes, especially those of *Taraktogenos kurzii* which seeds are known to produce the true chaulmoogra oil.

Hydnocarpus anthelmintica was obtained by Prof. Rock in Bangkok and Eastern Siam. Camp was established in the northern Lao States on Mt. Dai Chom Cheng and this mountain was explored for economic plants, among which species of *Castanea* or chestnuts, and a number of *Quercus* or oaks were secured. He followed the Meh Ping River by Lao houseboat to Rahong, a journey of ten days, making collections on the way. From Raheng he crossed overland with coolies to Moulmein, Burma, thence to Martaban, where *Hydnocarpus castanea* was obtained. The first specimen of *Taraktogenos*

kurzii encountered was at Thynganyinon, one day's journey from the Siamese Boundary in Burma. From Martaban he proceeded to Rangoon, thence to Monywa on the Upper Chindurin. From there he went by boat (stern-wheeler) to Mawlaik in northwestern Burma. At Mawlaik he was informed that *Taraktagenos kurzii* could be obtained near some jungle villages on the Khodaun stream. The best locality and where he found pure stands of *Taraktogenos kurzii* was near Kyokta, a small village of about thirty houses. Seeds were collected in large quantities and forwarded directly to Hawaii and Washington after the party again reached civilization. In northeastern Assam, in India proper, seed was secured of *Gynocardia odorata*, and of *Taraktogenos kurzii*, which is also found there.

Besides finding *Taraktogenos kurzii* and photographing it for the first time, Prof. Rock found a number of hitherto unknown species belonging either to *Taraktogenos* or *Hydnocarpus*.

Gathering of the seeds of the chaulmoogra oil tree has been a regular occupation of the natives for generations. This seed collecting, however, has been carried on very uneconomically because of the fact that the animals of the forest feed upon the fruit, and destroy a high percentage of seed, the natives getting only what the animals leave. The supply of seeds in the world's market is therefore very inadequate. Prof. Rock's work, therefore, was to find the trees that produced the seed and make collections of seed of *Taraktogenos kurzii* and other chaulmoogra oil-producing species so that the trees could be introduced in cultivation. This he succeeded in doing, traversing the forests of Siam and Burma where few white men had ever gone.

The Government of Hawaii has set aside one hundred acres of suitable mountain slopes for the planting of these species. The seeds brought back have all germinated and are growing well both in Hawaii and in this country.

Following Prof. Rock's address Dr. F. B. POWER, authority on the chemistry of the chaulmoogra oil, was called upon for remarks.

After expressing his appreciation of the interesting and instructive discourse by Professor Rock, Dr. Power spoke as follows:

"My attention was first particularly drawn to the subject of chaulmoogra oil while in London by an inquiry from the Leper Hospital at Robben Island, South Africa, respecting its active constituents. At about the same time it was recorded by Mr. E. M. Holmes (*Pharm. J.* 1900, **64,** 522; 1901, **66,** 596) on the authority of Sir David Prain, then Director of the Botanic Survey of India and now Director of the Royal Botanic Gardens, Kew, that chaulmoogra oil is not obtained from the seeds of *Gynocardia odorata* R. Br., as had previously been assumed, but from the seeds of *Taraktogenos kurzii* King. Shortly after these observations a large quantity of true chaulmoogra seeds was brought into the London market, and this afforded an opportunity for the investigation of the fatty oil expressed from them, which was conducted by me and my co-workers in the Wellcome Chemical Research Laboratories.

"A survey of the literature pertaining to chaulmoogra oil rendered it evident that very little of a definite nature was known regarding its constituents, and it was subsequently shown that the so-called "gynocardic acid," which had been stated to melt at 29.5° C. and was employed to some extent medicinally, consisted of a mixture of fatty acids. One of the first results of the investigation undertaken by us was the isolation of a beautifully crystalline acid, melting at 68° C., which was optically active, $[\alpha]_D + 56°$, and found to possess the formula $C_{18}H_{32}O_2$. This was designated *chaulmoogric acid*, with reference to the vernacular name of the oil. It exists in the oil as a glyceryl ester or

glyceride, and represents one of its chief constituents. Although chaulmoogric acid is isomeric with linolic acid, it is capable of absorbing but two atomic proportions of iodine or bromine, and therefore must contain in its structure a closed carbon ring, as has indeed been shown to be the case. A lower homologue of this acid was subsequently found in the oil, and on account of having first been isolated from the oils expressed from seeds of two species of *Hydnocarpus*, viz. *H. Wightiana*, Blume and *H. anthelmintica*, Pierre, it was designated *hydnocarpic acid*. This acid possesses the formula $C_{16}H_{28}O_2$, melts at 60° C., and, like chaulmoogric acid, is optically active, having $[\alpha]_D + 68°$. Many derivatives were made of these acids, including their methyl and ethyl esters, and their constitution was completely elucidated.

"In order to ascertain the character of the oil obtained from the seeds of *Gynocardia odorata*, a quantity of fresh material was specially collected for us in India. The examination of this oil showed it to possess none of the characters of true chaulmoogra oil, thus completely confirming the observations of Sir David Prain respecting the botanical source of chaulmoogra seeds. The gynocardia oil at ordinary temperatures is a liquid, whereas chaulmoogra oil is a soft solid. It is, furthermore, optically inactive, and contains none of the members of the chaulmoogric acid series, but more closely resembles linseed oil in its composition. Both the true chaulmoogra seeds and gynocardia seeds develop hydrogen cyanide in contact with water, showing the presence of a cyanogenetic glucoside. This substance has been isolated from the gynocardia seeds, and is a handsomely crystalline compound, possessing the formula $C_{13}H_{19}O_9N$, which has been designated *gynocardin*. It is accompanied in the seed by an enzyme termed *gynocardase*.

"The literature pertaining to all the above-mentioned investigations, to which several years were devoted, may be found in the *Transactions of the Chemical Society* of London, 1904, **85,** 838; 1905, **87,** 349, 884, 896; 1907, **91,** 557.

"Inasmuch as several articles have recently been published in this country and abroad, chiefly in the medical press, indicating that some new derivatives of chaulmoogra oil have been used in the modern treatment of leprosy, it seems desirable to note that such statements are evidently incorrect. The preparations employed have been the ethyl esters of chaulmoogric and hydrocarpic acids, which were first made and fully described nearly twenty years ago in connection with the investigations above cited. It is the use of these compounds by intramuscular injection, instead of the administration and external application of crude chaulmoogra oil, that has recently led to such successful results in the treatment of leprosy."

Fruit and seeds of the chaulmoogra oil tree were exhibited. One hundred and ten persons were present.

Following the meeting was a social hour with refreshments.

ROY G. PIERCE, *Recording Secretary.*

WASHINGTON ACADEMY OF SCIENCES

The 158th meeting of the Academy, held at the Public Library the evening of Thursday, October 20, 1921, was devoted to a discussion of *Readable Books in Science*, in connection with the list of "One Hundred Popular Books in Science," prepared at the suggestion of Dr. GEORGE F. BOWERMAN by a committee of the Academy and published in the Journal. (11: 353–366.

September 19, 1921.) The purpose of the list was discussed briefly by Doctor BOWERMAN, the methods of compilation and editing of the list by Dr. ROBERT B. SOSMAN, the mathematical, astronomical, and meteorological books by Dr. W. J. HUMPHREYS, the mineralogical and petrological books by Dr. E. T. WHERRY, and the botanical books by Dr. H. L. SHANTZ, following which there was a general discussion of the project by several of the previous speakers and by ALFRED H. BROOKS, W. L. SCHMITT, W. D. COLLINS, W. H. BIXBY, and others.

Adjournment was then taken to inspect the following three exhibits: (1) The one hundred popular books; (2) books suggested for the popular list, but not used; (3) books suggested for a proposed list of readable manuals or information books, such as a specialist in one field would recommend to another investigator who was quite unfamiliar with that field.

The 159th meeting of the Academy was held jointly with the Biological Society of Washington and the Botanical Society of Washington at the Cosmos Club the evening of Saturday, November 12, 1921. Professor ARTHUR DE JACZEWSKI delivered an address on *The Development of Mycology and Pathology in Russia*. He was followed by Prof. NICHOLAS I. VAVILOV, who spoke upon *Russian work in Genetics and Plant Breeding*. Following the presentation of these addresses Dr. VERNON L. KELLOGG, Permanent Secretary of the National Research Council, Dr. ERWIN F. SMITH, and others, spoke briefly of conditions in Russia and of the pleasant and mutually beneficial interrelations of Russian and American scientists.

The 160th meeting of the Academy was held at the Cosmos Club, the evening of Thursday, November 17, 1921, at 8:15. Dr. H. D. CURTIS, Director of the Allegheny Observatory, Pittsburgh, delivered a popular address on *The Sun, our nearest star.*

In introducing the subject, the speaker stated two simple equations: (1) Our sun = a star; (2) any star = a sun; which, though simple, are apt to be forgotten when one contemplates the Milky Way. Our own sun is but a unit in a collection of perhaps a thousand million closely similar suns forming our own stellar universe. There are, perhaps, a million other stellar universes, as large as our own and each with a billion suns, within the ken of our great telescopes. Our own sun, though 866,000 miles in diameter, and 1,300,000 times the volume of our earth, is a relatively insignificant star, which, if moved to the distance of the star clouds of the Milky Way, would appear merely as another faint point of light added to the rich complex. The mightiest stars, at their magnificent distances of hundreds or thousands of light-years, appear no larger in our greatest telescopes; for example, Betelgeuse, which in volume would probably contain 27,000,000 globes the size of our own.

The speaker discussed recent studies of the Sun—advances in photography and spectroscopic analysis, and their bearing on unexplained or little understood phenomena; theories designed to account for the peculiar law of rotation of the sun; sun-spots as high-temperature solar storms; their periodicity; the Sun as an almost infinitely old and wonderfully perfect heat-engine radiating heat at a temperature of between 5,000° and 8,000° C., with an energy of about 75,000 horsepower per square yard of sun surface; the age of the Sun, and hypotheses bearing upon the source of the Sun's heat; the wonderful balance of forces existing within the Sun; the correlation between changes in heat emission and terrestrial climatology, and its supremely important bearing upon the origin and maintenance of terrestrial life.

"As we contemplate the complexity of the details of the solar surface, the constant change of form in faculae, spots, and prominences, the balance of forces which has maintained the average energy of the Sun so constant for hundreds of millions of years is certainly a remarkable fact of nature, and lends indirect support to the postulation of an enormous duration of life for the average star.

"In our nearest star, then, we see a star which appears to be about an average star in surface characteristics, light emission, and size. It is a fair representative of the stars in general; there are literally tens of millions of copies of it out in space. This great heat-engine is pretty certainly a billion, and more probably a hundred billion years old. Certainly for 200,000,000 years, perhaps for a billion or more years, it has not varied permanently as much as 200° C. from its effective temperature of perhaps 5,600° C."

WILLIAM R. MAXON, *Recording Secretary.*